Recent Developments on Quarkonia Production from RHIC

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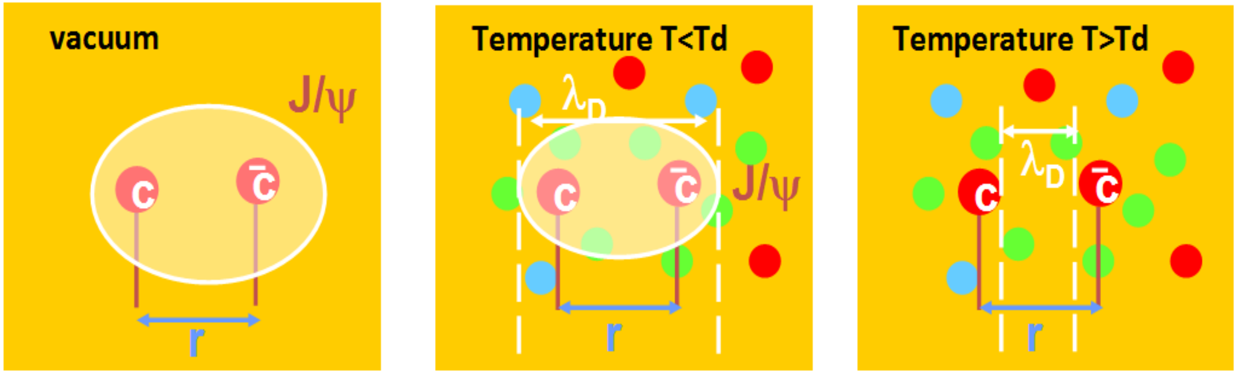
Outline

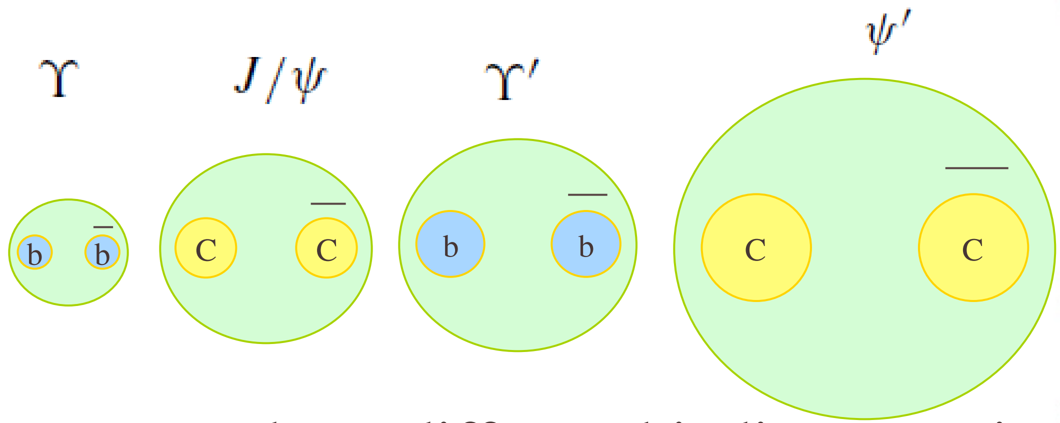
- Motivation: QGP and Quarkonia
- Experiments at RHIC: PHENIX and STAR
- Review of recent results
  - p+p, d+A and A+A
- Outlook
- Summary

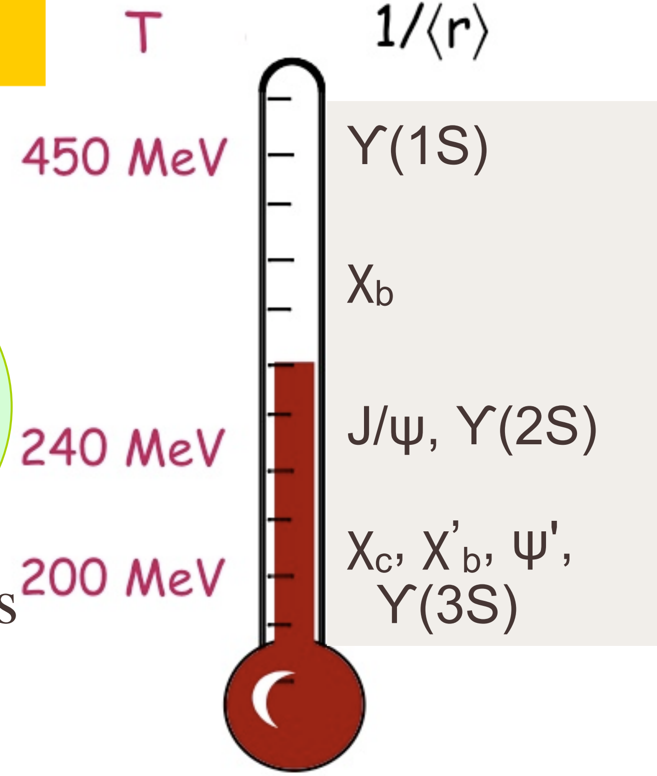
Quarkonia: A probe to QGP



Matsui & Satz
PLB 178, 416(1986

$$\lambda_D(T) = \sqrt{\frac{2}{9\pi\alpha_{\rm eff}}}\frac{1}{T}$$





Different states have different binding energies
Loosely bound states melt first!
Successive suppression of individual states provides a "thermometer" of the QGP

Mocsy & Petreczky
PRL. 99, 211602 (2007)

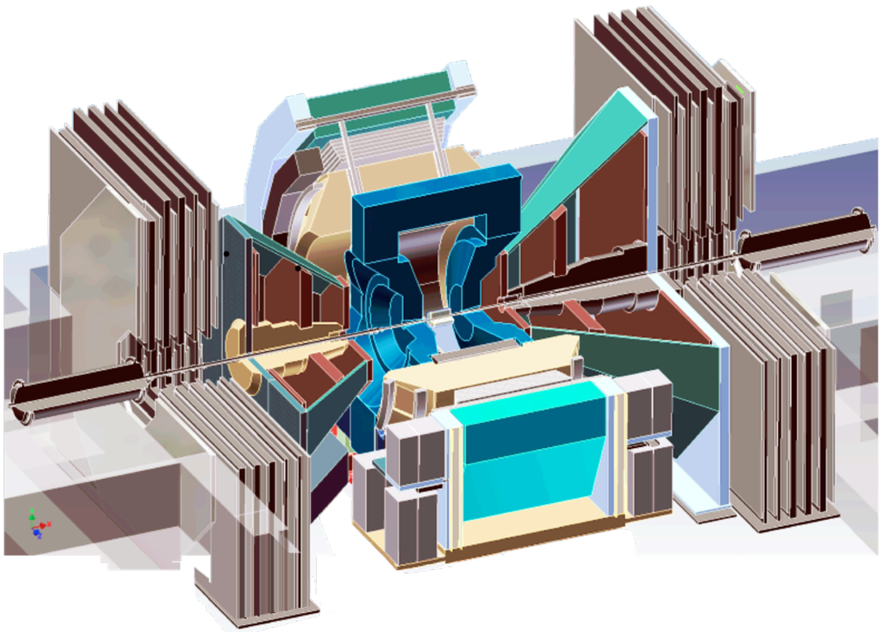
Relativistic Heavy Ion Collider

14 years, 14 Runs, 10 Energies, 7 Combination of Species

2001-2014	
Energies(CMS) GeV	Species
7.7, 9.2, 19.6, 22.4, 27, 39, 62.4, 130, 200, 500	p+p, Au+Au, d+Au, Cu+Cu, Cu+Au, U+U, He3+Au

The Experiments

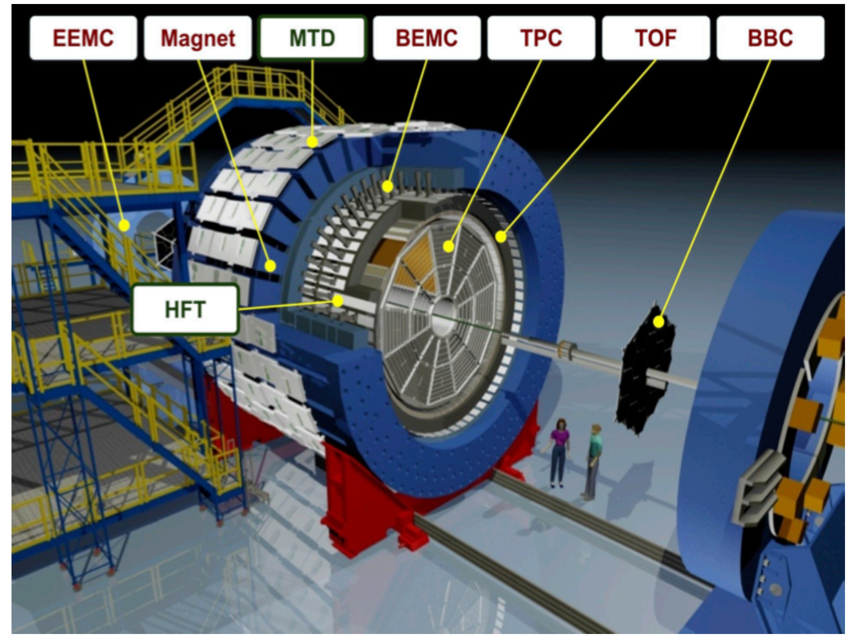
PHENIX



Acceptance: $|\eta| < 0.35$,

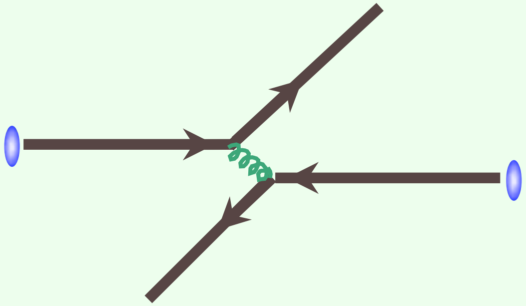
$1.2<|\eta|<2.2$

STAR



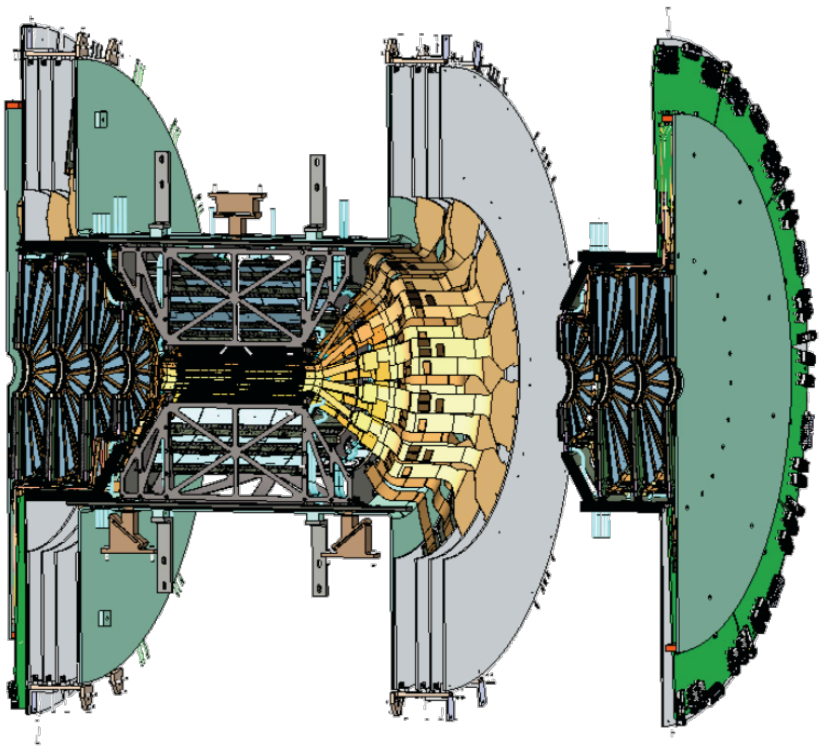
Acceptance: $-1 < \eta < 1$

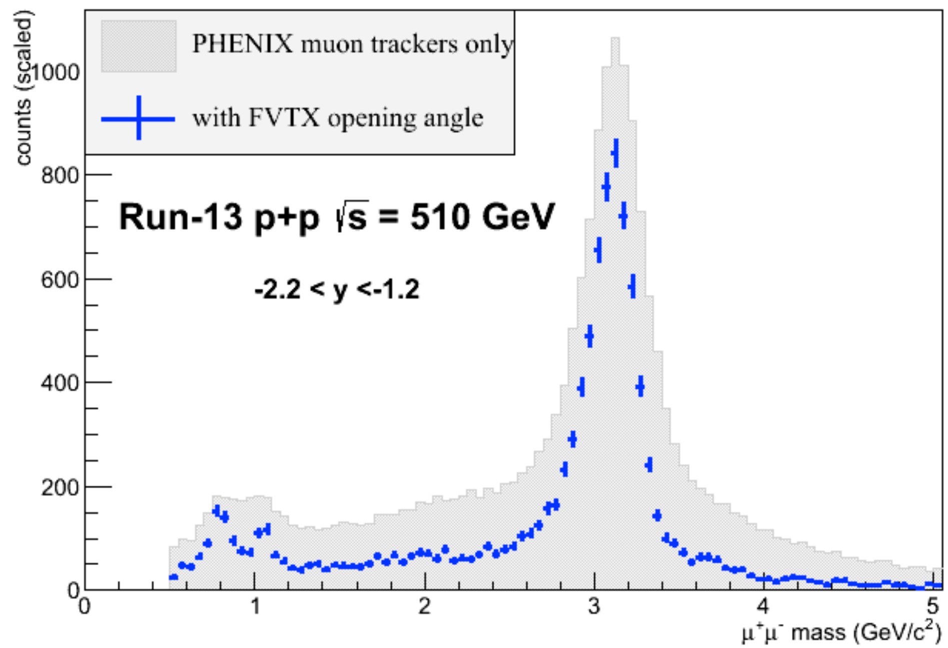
p+p measurements



New FVTX detector at PHENIX

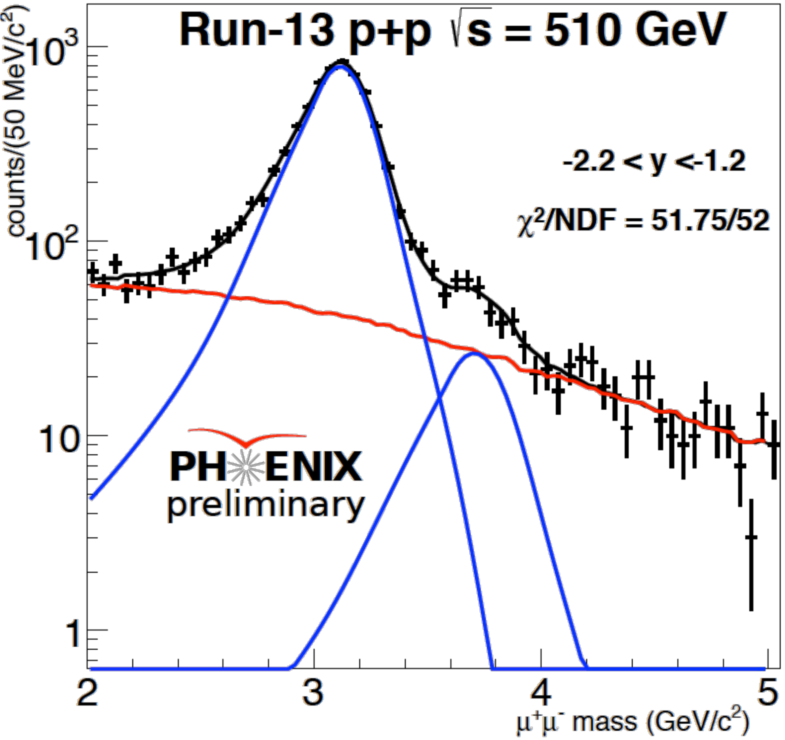
Forward Silicon Vertex Tracker in PHENIX

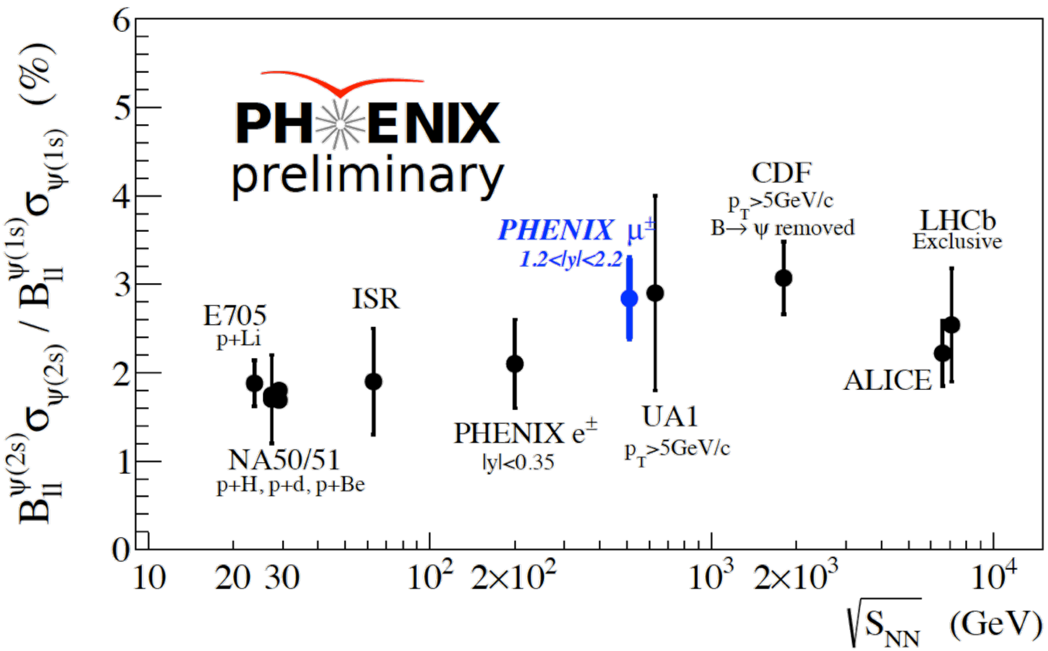




Improved mass resolution and background rejection

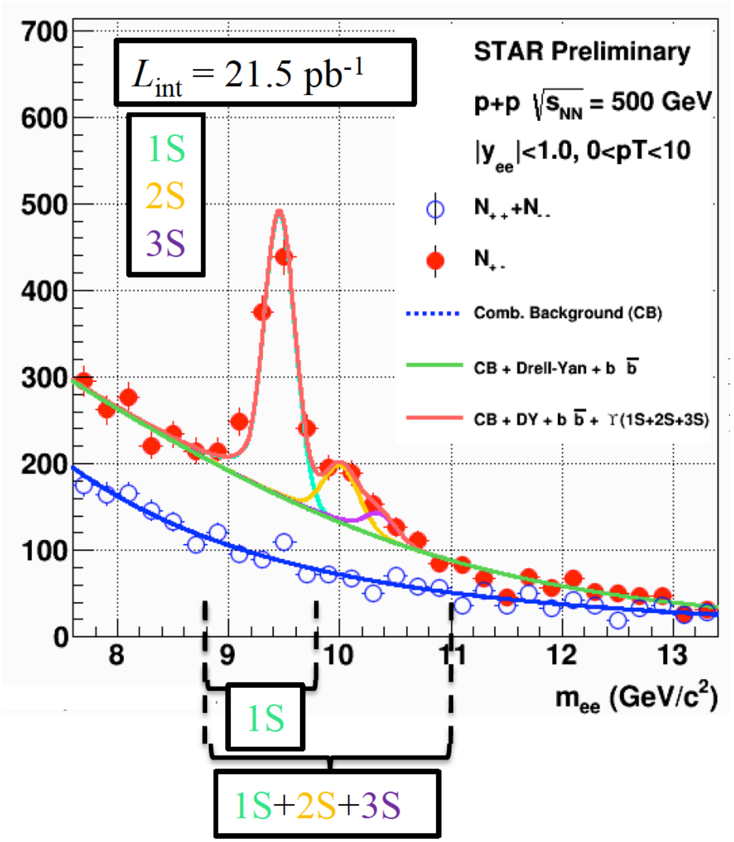
ψ' in Forward Rapidity

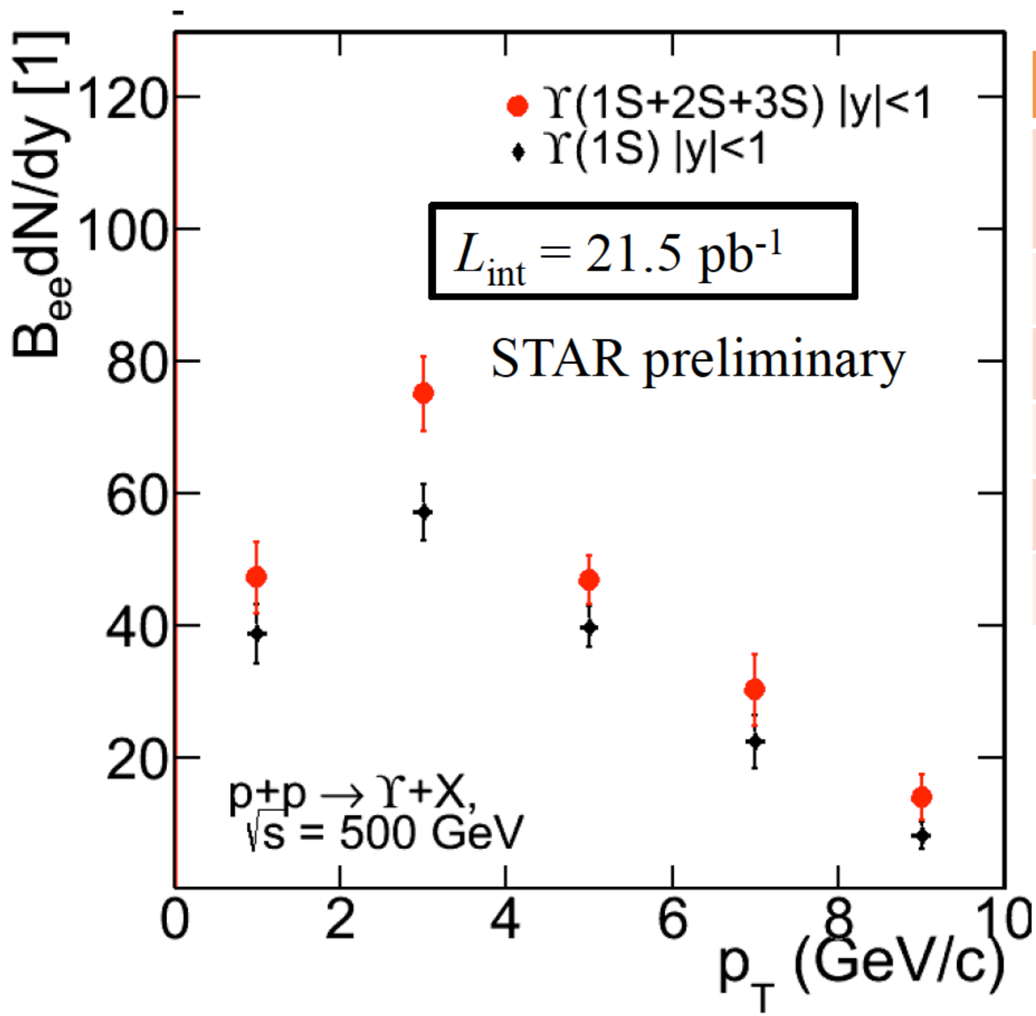




First measurements of ψ'/J/ψ in the forward rapidity at RHIC.
Consistent with the world data.

Υ in p+p from STAR

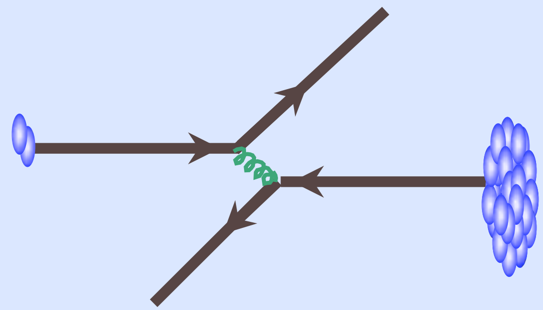




Upsilon signal upto 10 GeV

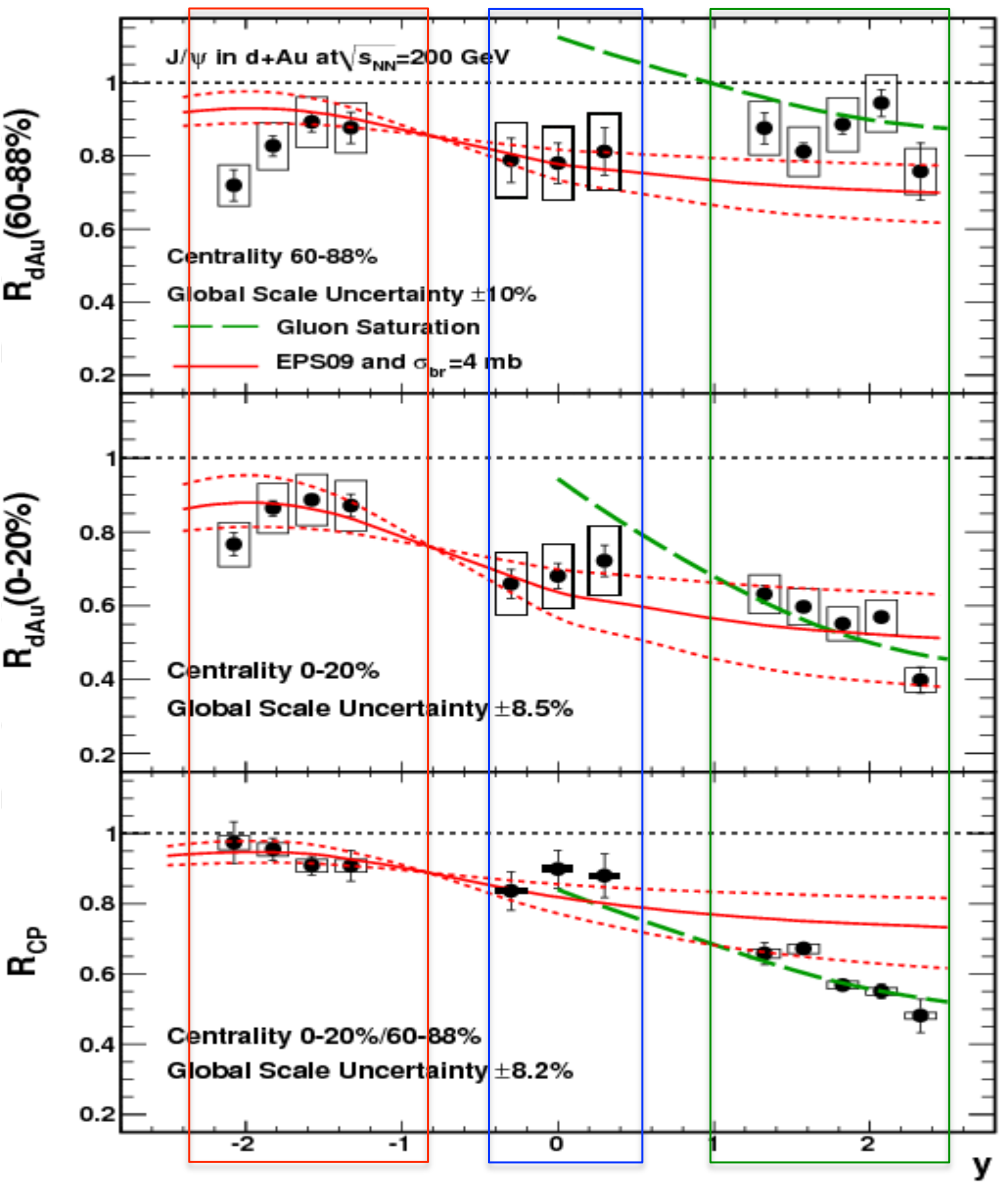
L. Kosarzewski
Hot Quarks 2014

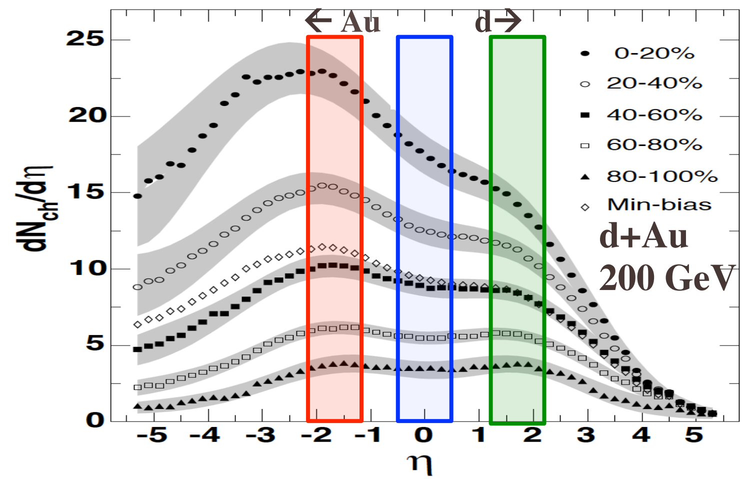
d+A measurements



probe CNM effects

J/ψ suppression in d+Au



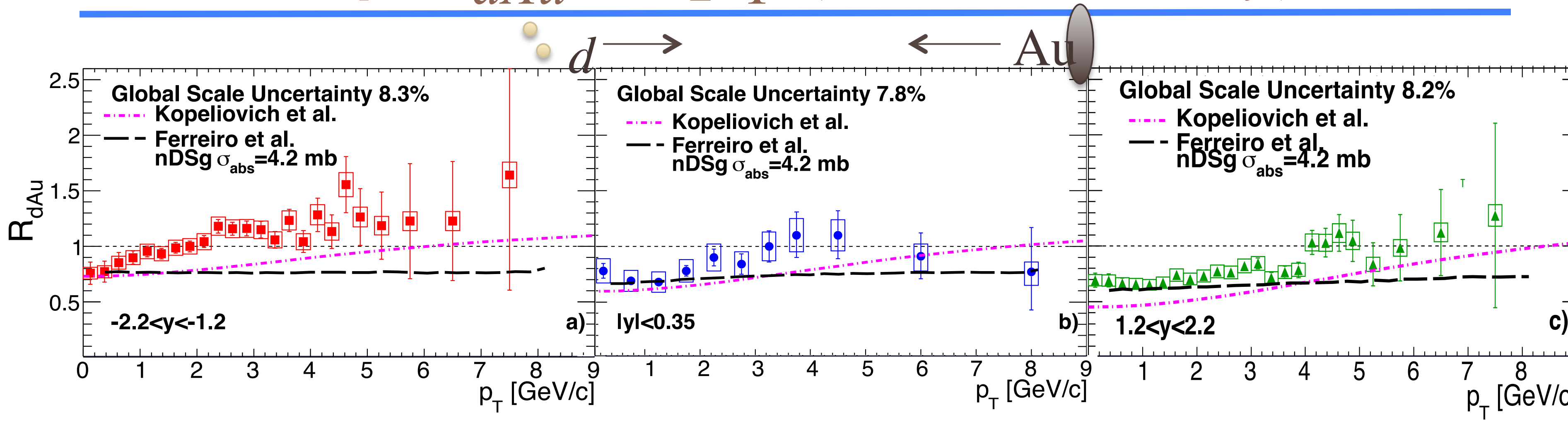


A reasonable agreement with EPS09 nPDF + σ_{br} = 4 mb for central collisions but not peripheral.

Nuclear PDF seems to have stronger than linear nuclear thickness dependent.

PRL 107, 142301 (2011)

$J/\psi\ R_{dAu}$ vs. p_T (all centrality)



R_{dAu} rises out to p_T~5 GeV/c at all rapidities.

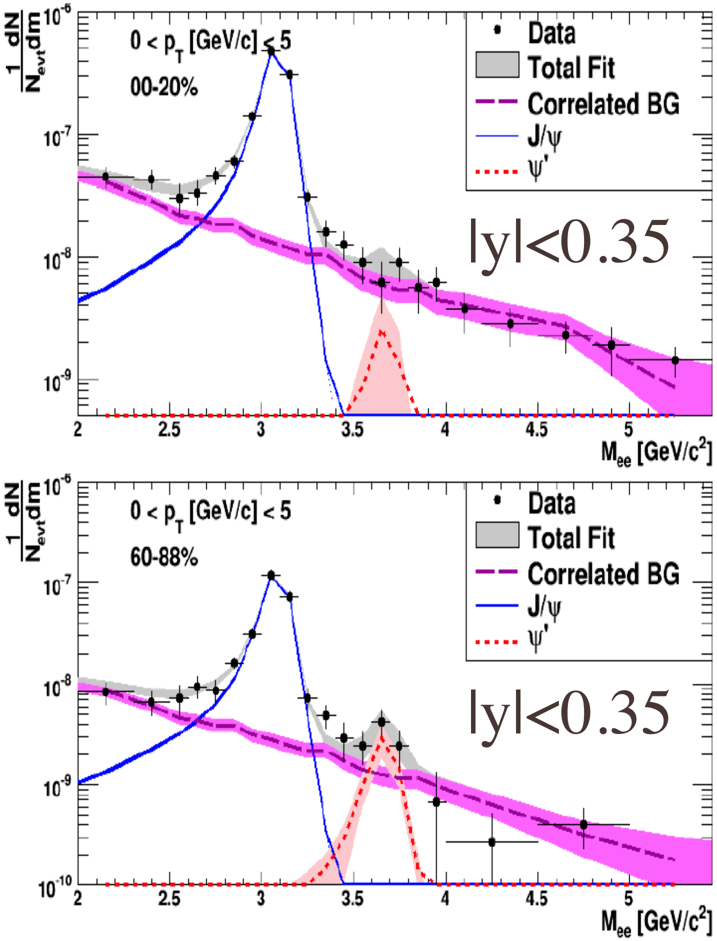
Largest disagreement with models is at backward rapidity.

Shadowing + σ_{br} model (no Cronin) does not match the qualitative trend.

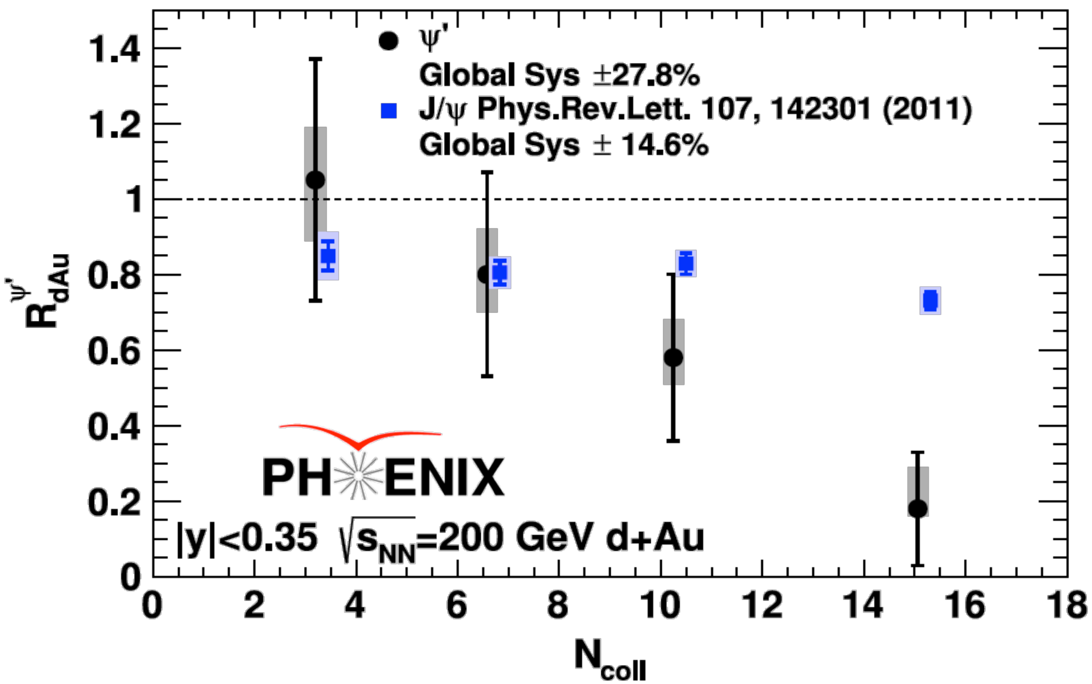
Model by Kopeliovich et al. includes Cronin and σ_{br} prediction, qualitatively matches the p_T shape.

Phys. Rev. C 87, 034904 (2013)

ψ’ R_{dAu}



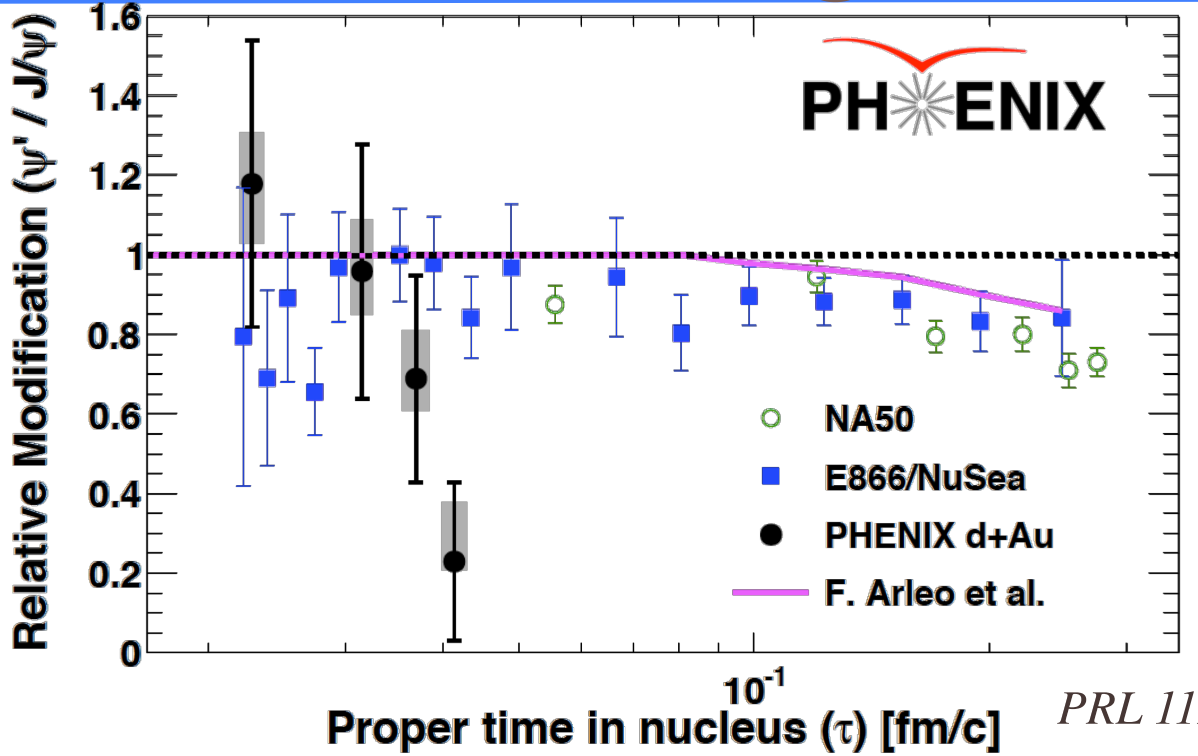
PRL 111, 202301 (2013)



Strong suppression of y’ with increasing N_{coll} at the mid-rapidity.

Very unexpected results!!

Nuclear crossing time



PRL 111, 202301 (2013)

After ccbar formation, the pair expands as it crosses nucleus. Break-up makes sense **ONLY** on time scales larger than charm pair formation time.

Formation time ~ 0.15fm

Nuclear crossing time ~0.05 fm at RHIC at midrapidity

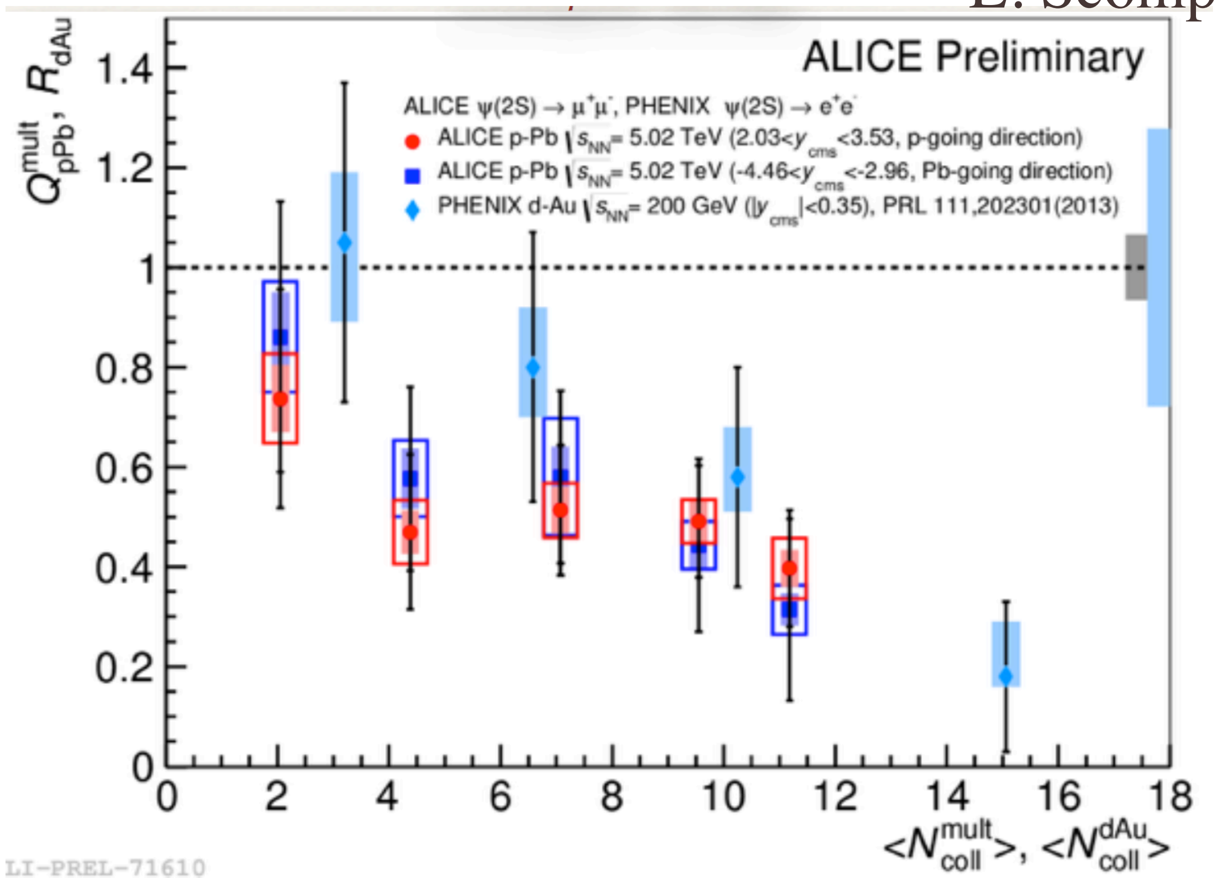
Precursor crosses nucleus before final state forms! *ψ' / J/ψ* ratio should be ~1

Suppression outside the nucleus?

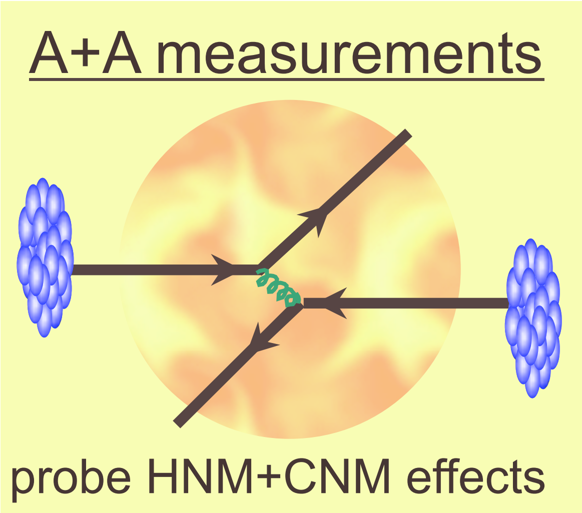
Small QGP? Or co-movers?

Confirmed by LHC

E. Scomparin, INT 2014

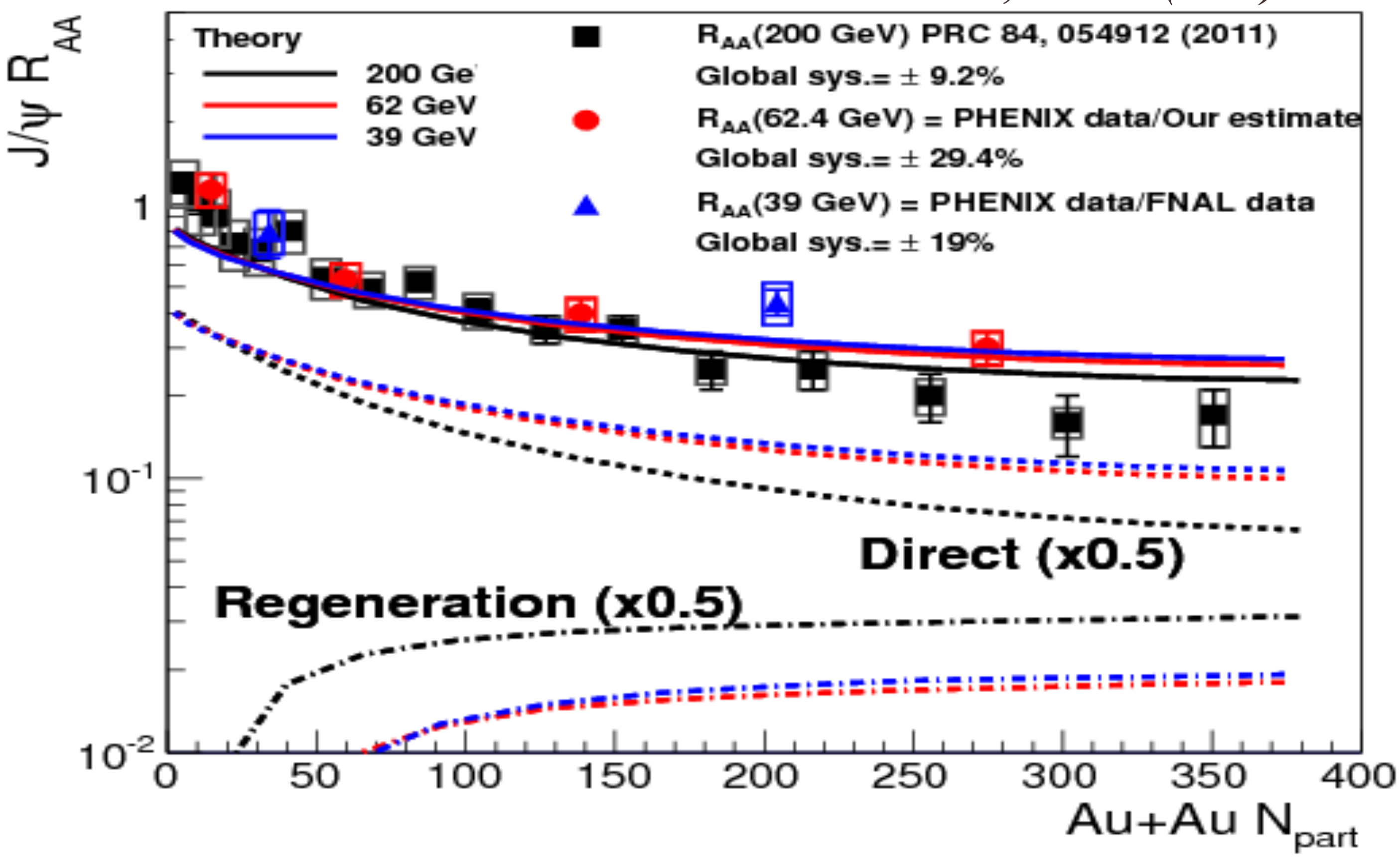


Similar affect seen at ALICE experiment.
Even a smaller nuclear crossing time at LHC.


A+A measurements
probe HNM+CNM effects

Energy variation (62 and 39 GeV)

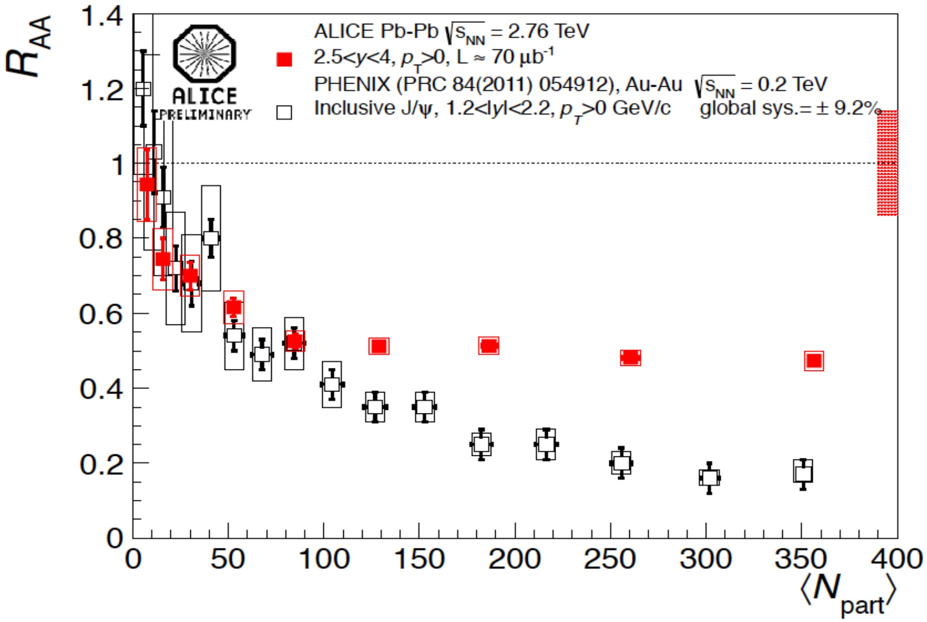
PRC 86, 064901 (2012)

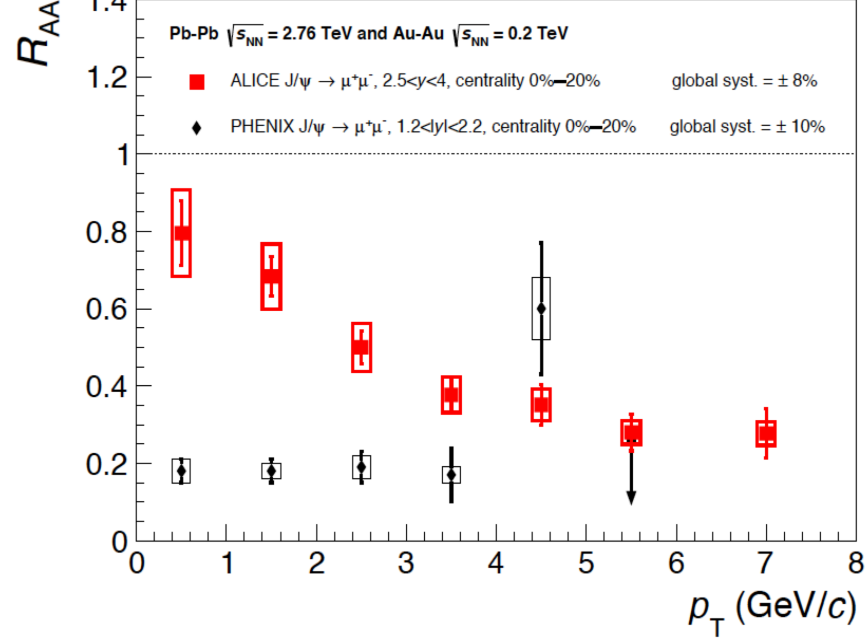


Similarity in J/ψ R_{AA} at different energies is due to the competing effects of dissociation and regeneration.

J/ψ at LHC

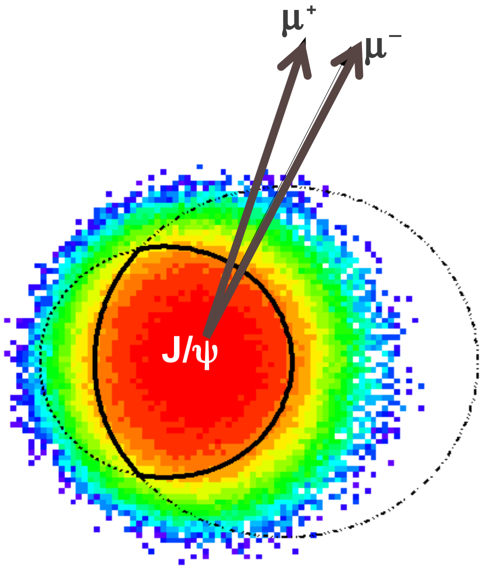
PLB 734 314-327

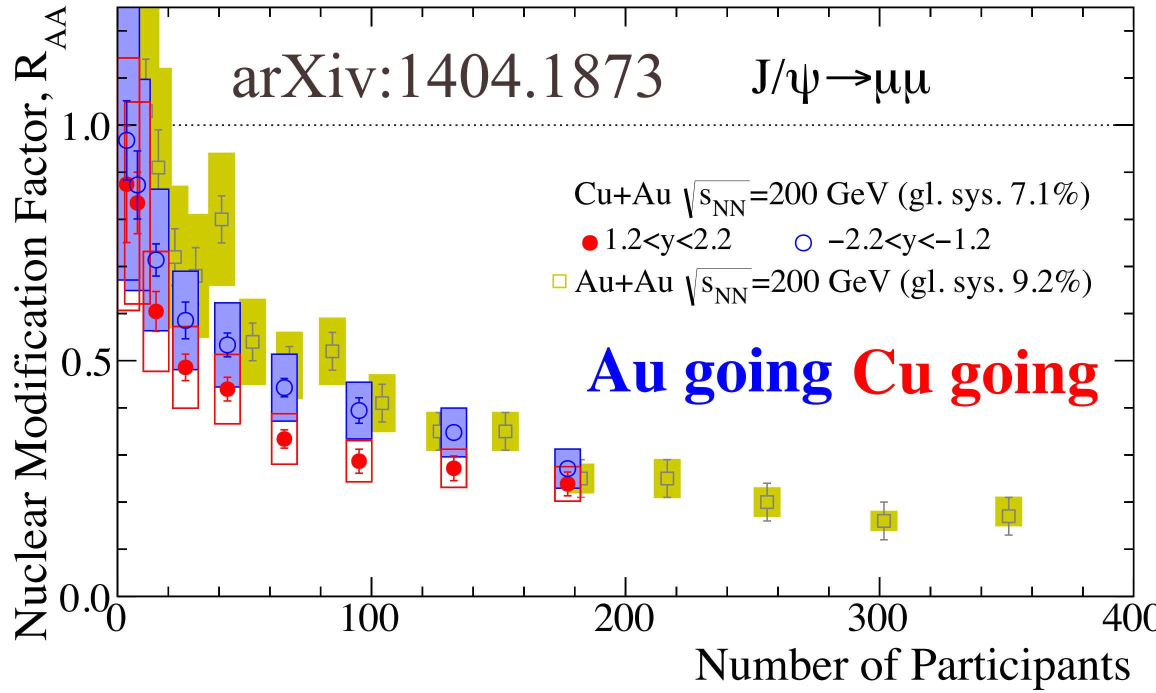




Large R_{AA} at low pT and large v_2 confirms higher recombination at LHC energies

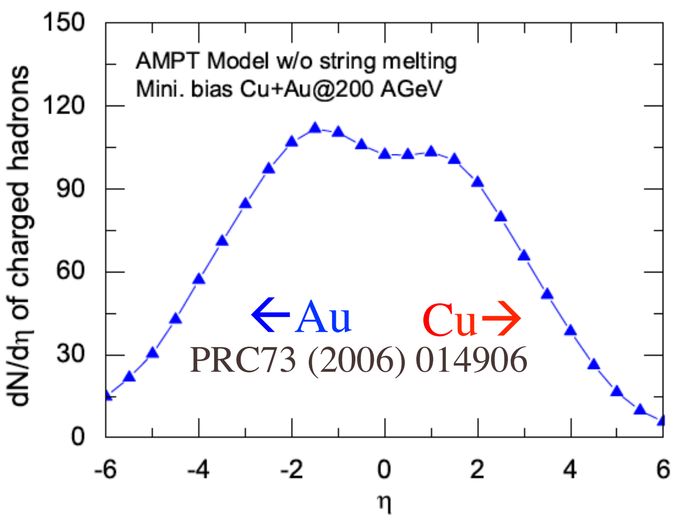
Cu+Au (new Geometry)





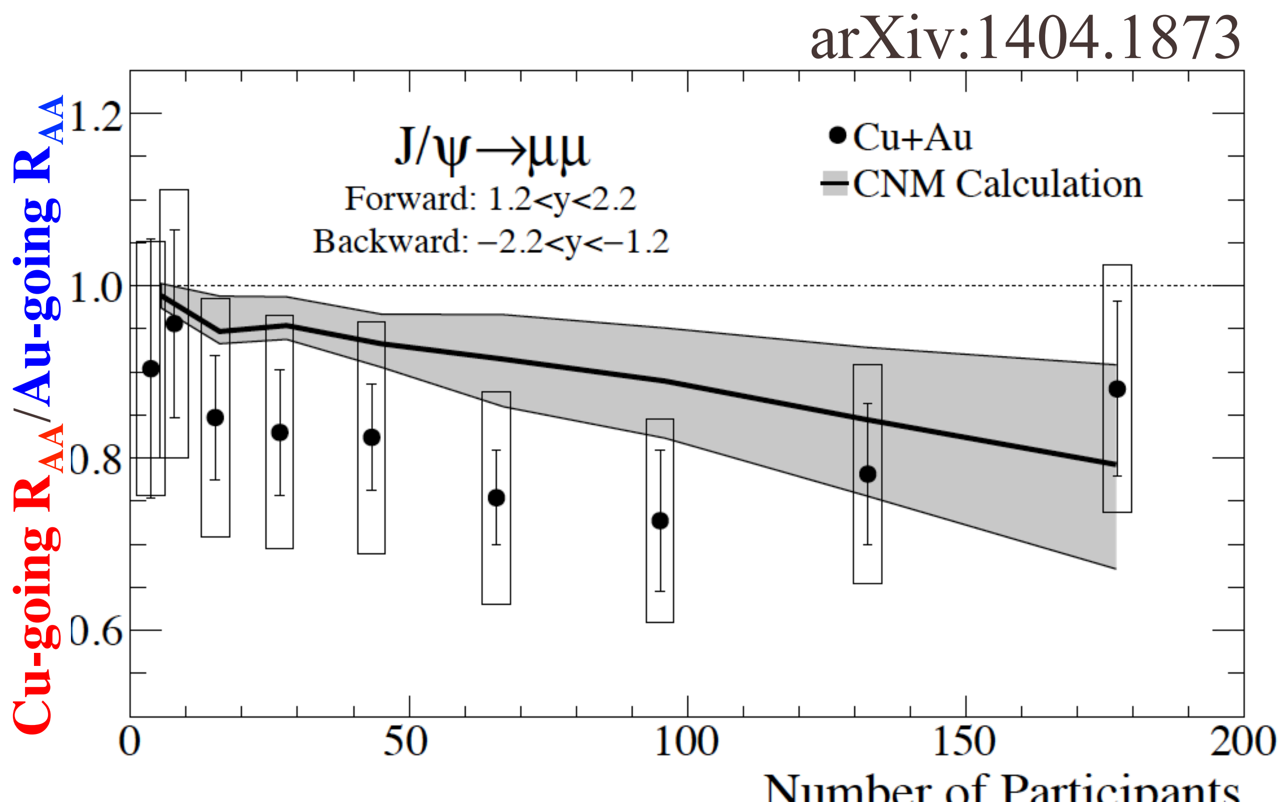
Higher suppression in region of lower particle density. Similar to d+Au collisions.

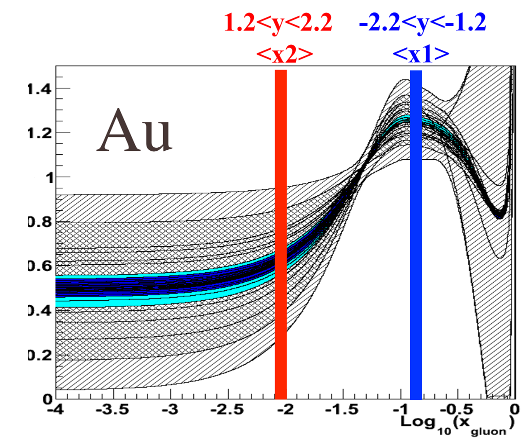
Suppression due Debye screening would have gone in other direction.

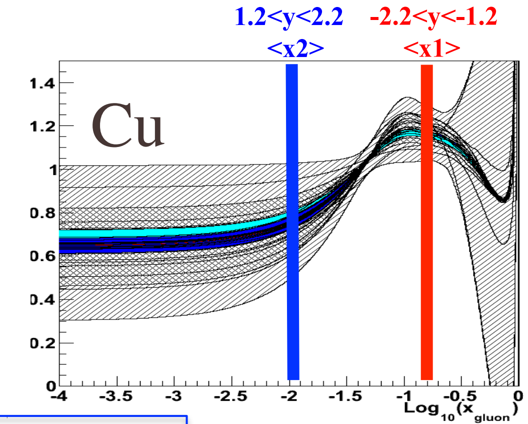


Asymmetric nuclear effects

Cu-going-side/Au-going-side





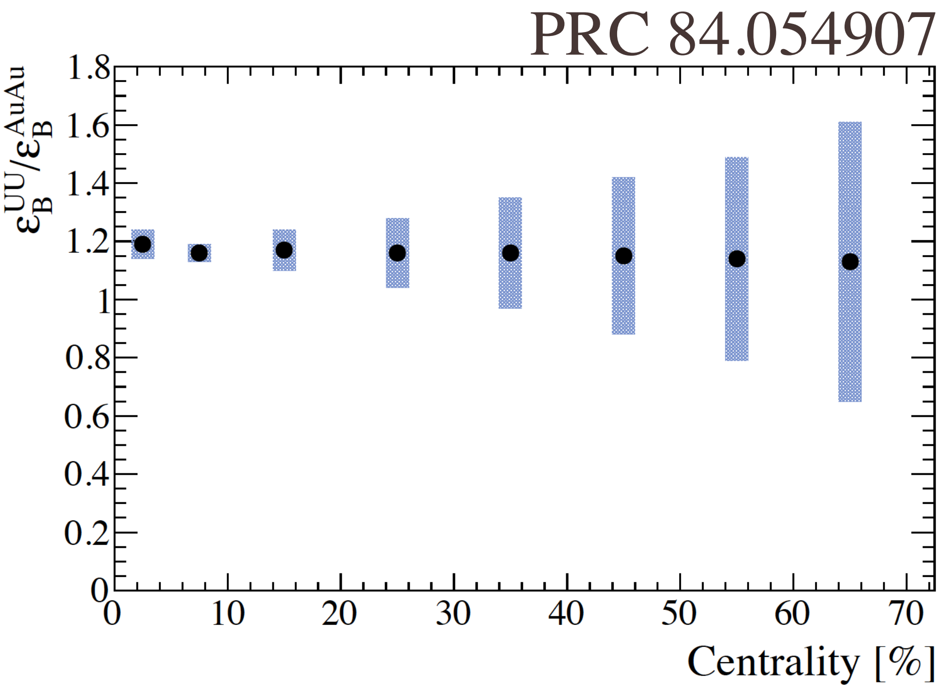


EPS09 with linear thickness dependence explains the data well.

Au-going direction :
low-x partons in Cu nucleus * high-x partons in Au nucleus

Cu-going direction:
low-x partons in Au nucleus * high-x partons in the Cu nucleus

U+U (new Geometry)

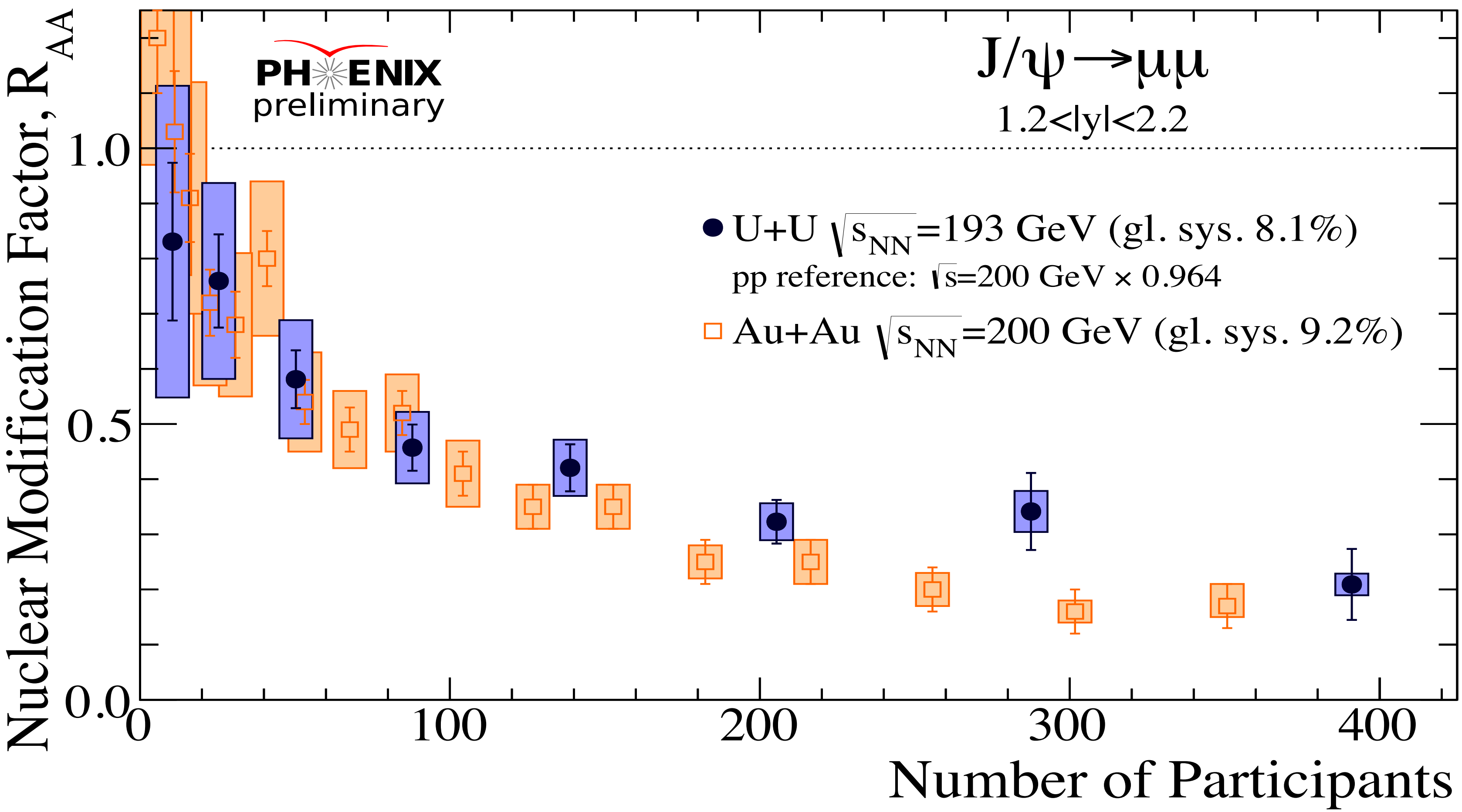


Higher energy density

Higher recombination

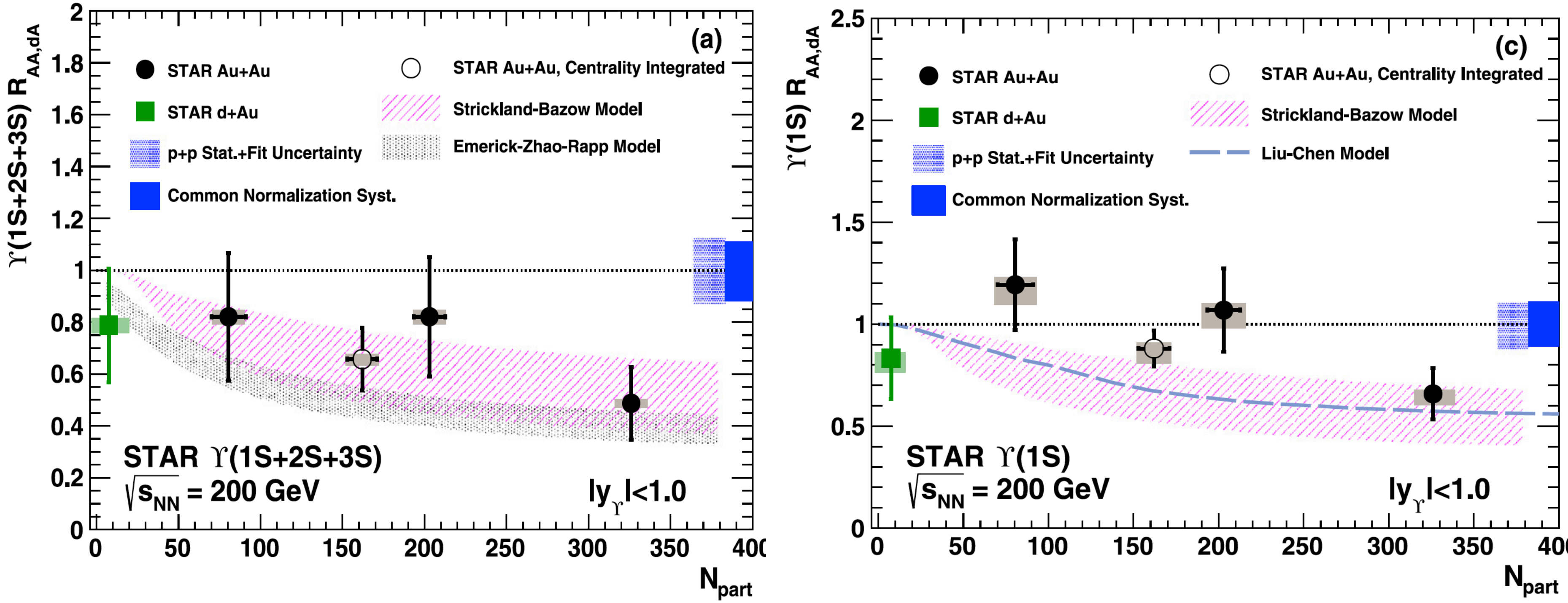
$$N_{J/\psi}^{stat} \propto N_c^2$$

R_{AA} in U+U



Weaker suppression?
Higher recombination?

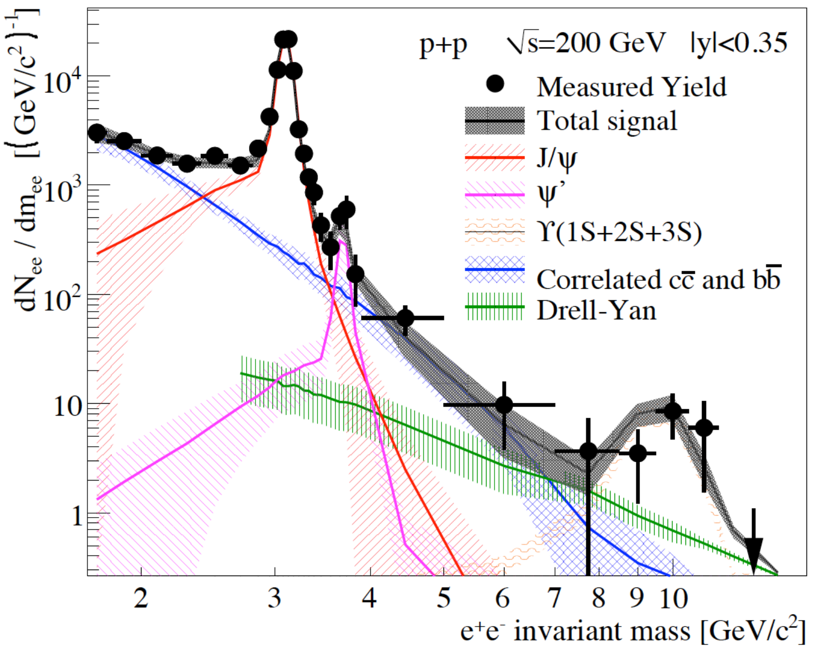
Υ R_{AA} at STAR



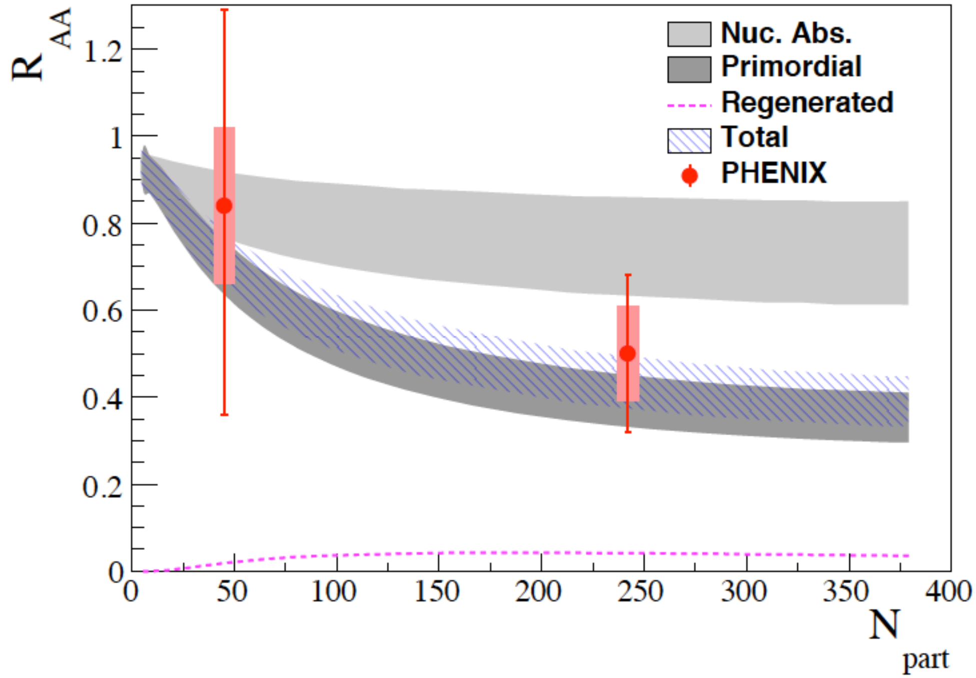
R_{AA} for Υ (1S) and Υ (1S+2S+3S) as function of N_{part}.
Stronger suppression for the higher states than Υ (1S).

PLB 735 (2014) 127

Υ at PHENIX



arXiv:1404.2246



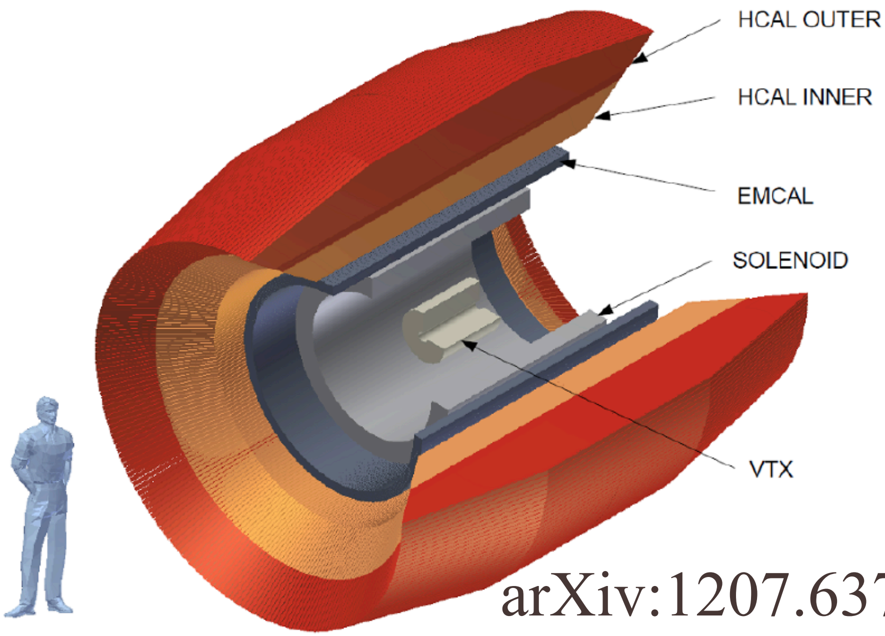
RAA similar to STAR.

Model explains the data very well.

Future of quarkonia at RHIC

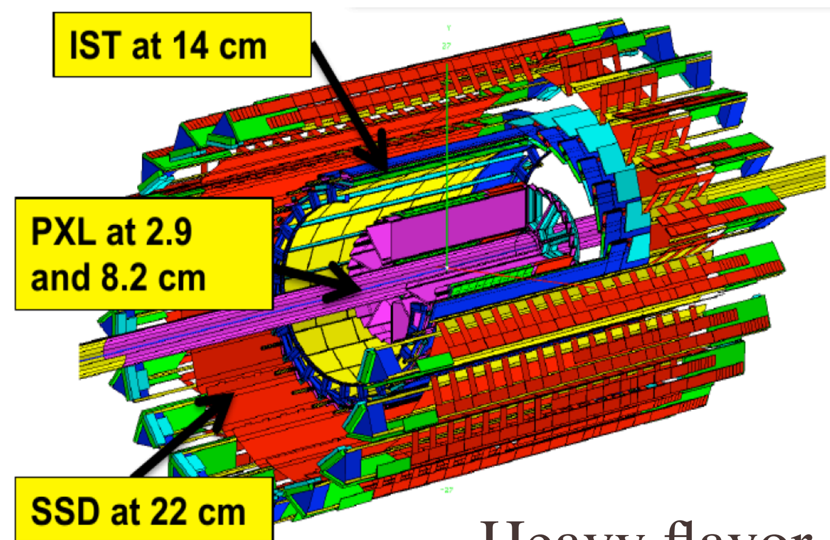
Au+Au (2014) and p+A (2015) dataset with additional detector capabilities from both experiments.

sPHENIX (Long term)



arXiv:1207.6378

STAR



Heavy flavor tracker

Talk by Marzia Rosati.

Summary

- Both PHENIX and STAR measured quarkonia states in a wide range of kinematic ranges and collision species.
- The magnitude and trend of ψ(2s) suppression in nuclear collisions is quite different from J/ψ. Nuclear crossing time does not explain the data.
- In Cu+Au collision, the Cu going side is more suppressed than Au going side due to CNM effects, sensitive to the low x of the Au nuclei.
- Measured Υ R_{AA} consistent with melting of Υ(2S) and Υ(3S) states.
- New detector capabilities will allow more precise studies in near future.

BACK-UPS